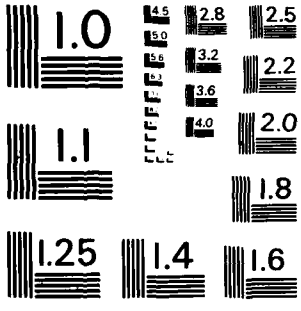
AD-A125 814 FLIGHT AND SIMULATION TEST ANALYSIS SYSTEM(U) GEORGIA INST OF TECH ATLANTA ENGINEERING EXPERIMENT STATION R N SEITZ JAN 83 GIT/EES-A-3167-001 DRSMI/RD-CR-83-7 1/1

UNCLASSIFIED DAAH01-81-D-A003 F/G 9/2 NL

END
DATE FILMED
4 83
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

TECHNICAL REPORT RD-CR-83-7

FLIGHT AND SIMULATION TEST ANALYSIS SYSTEM

R. N. Seitz
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, GA 30332

JANUARY 1983

Prepared for
Systems Simulation and Development Directorate
US Army Missile Laboratory

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

Approved for public release; distribution unlimited.

DISPOSITION INSTRUCTIONS

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

DISCLAIMER

THE FINDINGS IN THIS REPORT ARE NOT TO BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION UNLESS SO DESIGNATED BY OTHER AUTHORIZED DOCUMENTS.

TRADE NAMES

USE OF TRADE NAMES OR MANUFACTURERS IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL INDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL HARDWARE OR SOFTWARE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RD-CR-83-7	2. GOVT ACCESSION NO. AD-A125614	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FLIGHT AND SIMULATION TEST ANALYSIS SYSTEM		5. TYPE OF REPORT & PERIOD COVERED Final Report 8 Feb - 31 Aug, 1982
		6. PERFORMING ORG. REPORT NUMBER A-3167-001
7. AUTHOR(s) R. N. Seitz		8. CONTRACT OR GRANT NUMBER(s) DAAH01-81-D-A003 Delivery Order 0040
9. PERFORMING ORGANIZATION NAME AND ADDRESS Georgia Institute of Technology Engineering Experiment Station Atlanta, Georgia 30332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Missile Command Redstone Arsenal, AL 35898 Attn: DRSMI-RPT		12. REPORT DATE January 1983 13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U.S. Army Missile Command Redstone Arsenal, AL 35898 Attn: DRSMI-RDF/Hallum		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

This document has been approved for public release and sale; its distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Product Improvement Funding, Data Analysis, Data Reduction, Flight Test, Simulation, Ground Station, Interactive Data Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The goal of this study was to propose an equipment configuration for the Flight and Simulation Test Analysis System based on potential users needs, and to conduct compatibility studies between various models of the proposed equipment. The Flight and Simulation Test Analysis System is intended to be a data analysis facility to improve engineering productivity by assimilating data from either flight tests or flight simulations and then analyzing and plotting the data for the engineering staff at interactive terminals.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This report was prepared by the Electromagnetics Laboratory of the Engineering Experiment Station, Georgia Institute of Technology, under Contract No. DAAH01-81-D-A003, Delivery Order No. 40, for the U.S. Army Missile Command. The contract technical monitor was M. M. Hallum and the contract project monitor was D. L. Cobb, DRSMI-RDF, both from the Systems Simulation and Development Directorate of the U.S. Army Missile Command. The contract period extended from February 8, 1982 through August 31, 1982.

The views and conclusions in this document are those of the author and should not be interpreted as necessarily representing the official policies of the U.S. Army Missile Command.

The author would like to gratefully acknowledge the invaluable contributions of D. L. Cobb.

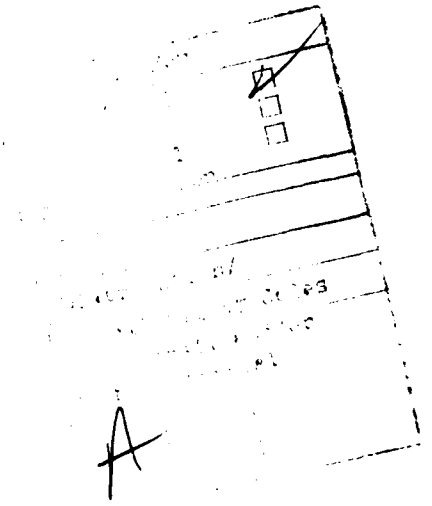


TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

I. OBJECTIVES AND BACKGROUND

A. Task Objectives

The goal of this study was to propose an equipment configuration for the Flight and Simulation Test Analysis System based on potential users needs, and to conduct compatibility studies between various models of the proposed equipment.

B. Background

The Flight and Simulation Test Analysis System is intended to be a data analysis facility to improve engineering productivity by assimilating data from either flight tests or flight simulations and then analyzing and plotting the data for the engineering staff at interactive terminals.

The principal components of the system will be a data reduction ground station and Fourier Analyzer, a time-sharing minicomputer, and a number of interactive graphics engineering terminals.

In addition, the system will interface, on-line or off-line, with the Hawk radome positioner and a laser tracker. Figure 1 graphically depicts this layout.

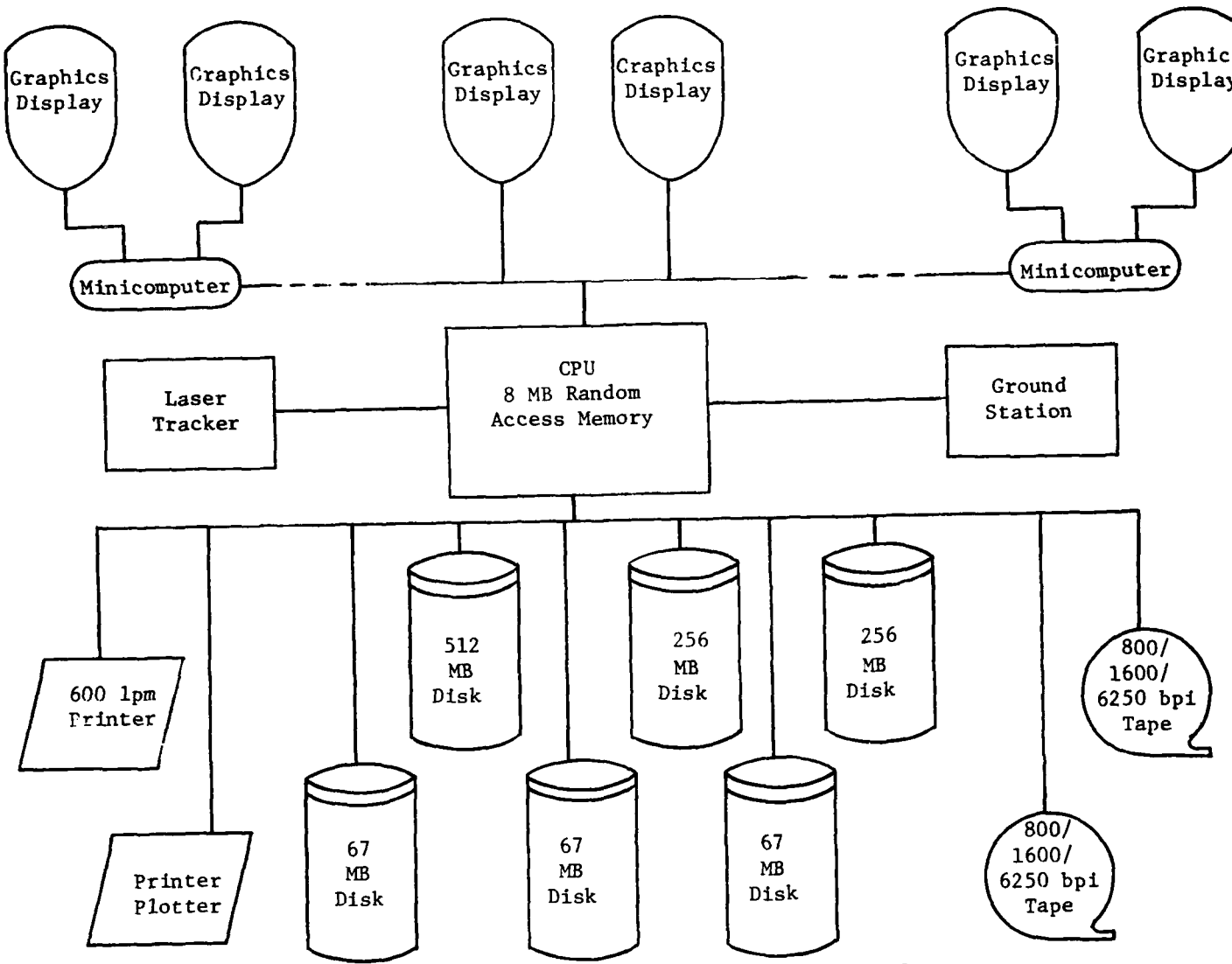


Figure 1. Flight And Simulation Test Analysis Layout System.

II. COMPATIBILITY REQUIREMENTS

A. Survey of User Requirement

An initial survey of user requirements was conducted among members of the Systems Evaluation Branch of the U.S. Army Missile Command (MICOM) and their contractor personnel with the Georgia Institute of Technology and the University of Alabama in Huntsville. The following remarks summarize the results of this survey.

1. Compatibility with Control Data Corporation Equipmer

Most of the users expressed a desire for additional Tektronix storage-display terminals. The users also felt that desk-t quick-look graphics capabilities would be useful, provided that centi site storage display backup would be available. Color graphical disp. capability was felt to be useful at a central location but only in conjunction with color hard-copy capability. Most users expressed a desire for light-duty, hard-copy units (printer/plotters or photocopies) at local or desk-top terminals. Little need was expressed for hard-copy input devices (graphics tablets, cursor readers, etc.) other than at a central site. Some users desired personal computers as terminals while others were neutral on this subject.

In the event that CDC compatibility could not be achieved, these users strongly desired a link to MICOM's Cyber 176 computer that would permit them to initiate jobs on the Cyber 176, and to receive data files from the Cyber for subsequent plotting and evaluation. In the event that a link to the Cyber 176 could not be made available, these users strongly desired that their graphics terminals be able to access MICOM's Cyber 176 and CDC 6600 computers directly. They were concerned about the lack of ownership within the Branch of Tektronix graphics terminals which could access the CDC computer.

2. Terminal Equipment Requirements

Some of the potential users surveyed had little present need for computers and were not sure how or whether they would use one in the future.

3. Attitude Toward Perkin-Elmer Computers

Most of the personnel interviewed during the survey were negative about Perkin-Elmer equipment because of bad experience or perceptions regarding the Perkin-Elmer(P-E) equipment located in the Directorate.

4. User Perception of Future Computer Needs

More than half of the 20 personnel interviewed ran large programs on the Control Data Corporation (CDC) 6600 and the Cyber 176 computers. They were well pleased with these computers and felt that their programs could only be converted to another computer at great expense. These users strongly favored acquiring a CDC-compatible computer.

5. Ground Station Equipment Requirements

Some users had a requirement for a ground station to reduce large quantities of complex analog test data for the Pershing II and HAWK flight test and simulation programs. This requires the conversion to engineering units and to digital format of several thousand analog tape records and the Fourier analysis of flight test and simulation results. The Pershing II data is recorded on a sizable number of channels and includes subcommutated frames.

B. Different Compatibility Criteria

There were several independent compatibility requirements that probably could not all be satisfied simultaneously.

1. Compatibility With Existing Control Data Corporation Computer Programs

The user requirements survey (Section II) revealed that a number of the users surveyed had large computer programs which run on CDC computers, and which may be prohibitively expensive to convert to a non-CDC computer. From this standpoint, the new computer should be compatible with the CDC 6600 and/or Cyber 176 computers.

2. Compatibility With the Directorate's Perkin-Elmer Computers

The Systems Simulation and Development Directorate owns a P-E 3220 computer and an Interdata (P-E) 8/32 computer. Hardware and software compatibility with these P-E computers would be highly desirable.

3. Compatibility With Fairchild-Weston Systems Corporation (EMR) Ground Station Equipment

The Flight and Simulation Test Analysis System will require ground station equipment to analyze flight test data tapes generated by the White Sands Missile Range and the Eastern Test Range. The two test ranges generate these tapes on EMR ground station equipment. The Flight and Simulation Test Analysis System should include EMR telemetry data reduction equipment to be compatible with the equipment at these test

ranges, and also with other EMR data reduction equipment owned by the U.S. Army Missile Command (MICOM). However, EMR hardware and software is designed to be interfaced only to Digital Equipment Corporation (DEC) computers, leading to a requirement, on hardware compatibility grounds, for the DEC VAX (Virtual Access) 11/780 computer.

4. Compatibility with Other U.S. Army and Contractor Computer Software

The U.S. Army has selected the DEC VAX computers for implementation of the new DOD standard programming language, ADA, leading to a requirement for compatibility with the DEC VAX computer family. (Perkin-Elmer has been designated to play a similar role for the U.S. Air Force.) Also, because of the widespread popularity of the VAX computer family, a number of contractor programs of interest to MICOM have been written for the VAX computers.

This latter VAX computer compatibility advantage may be offset to a greater or lesser extent by the fact that Perkin-Elmer 3200 computers are designed to facilitate real time simulations, so that a disproportionate number of simulation programs may exist that run on P-E computers.

5. Maintainability and Compatibility with Other Army Missile Command (MICOM) Computers

Maintenance of computers is a key problem within MICOM. MICOM owns several Gould/Systems Engineering Laboratories (SEL) 32/77 and 32/87 computers and a Harris computer. These are covered under an omnibus maintenance contract that could be expanded to cover this proposed Flight and Simulation Test Analysis System if Harris or Gould/SEL computers were chosen.

6. Compatibility with Future Needs

In reviewing computer compatibility and user requirements, it may be desirable to consider future user needs and technological trends within the computer industry over the assumed ten-year lifespan of this equipment. Computer requirements at MICOM will probably be driven by the sizes of the computer programs delivered to MICOM by contractors and other government agencies. These program sizes, in turn, will probably be limited only by the computer resources which advancing technology makes available to the programmer, as has been the case for the past 30 years. To get a basis for projecting future trends, it may be helpful to look back at minicomputer technology in 1972. Two of the most advanced minicomputers of that day were the Harris 6024/1 and the DEC PDP 11/45. The Harris 6024/1 was limited to 192 kilobytes of 600 nanosecond core memory and utilized 56 megabyte disk drives, while the PDP 11/45 was limited to 248 kilobytes of 850 nanoseconds core memory and similar sized disk drives. The largest computer available in 1972, the IBM 370/165, could support eight megabytes of core memory and employed 100 megabyte disk drives.

Extrapolating computer technology to the year 1992 would lead to a forecast of minicomputer random access memory storage capacities of one-fourth to one gigabytes and disk storage capacities of one to four gigabytes per disk drive. Random access memory (RAM) should cost $100-200 per megabyte (MB) and 32-bit desktop computers with 1 to 16 MB of virtual access RAM and 50 to 200 MB of disk storage should be commonplace by 1992. Thus, the central processing unit of the Flight and Simulation Test Analysis System will seem small and obsolete by 1992, even with maximum available RAM (8 to 16 MB) and 1,000 MB of disk storage.

C. Resolution of Competing Compatibility Requirements

1. Compatibility at the FORTRAN VII Source Code Level

In principal, computer programs can easily be converted from one computer to another if they are written in the ANSI FORTRAN VII source language. However, some major problems emerged in one major test case carried out jointly for this study and for a Pershing II task where an effort was made to convert a TRW simulation program from a VAX 11/780 to MICOM's PE-3220 computer. First, TRW had availed themselves of programming extensions supported by the VAX FORTRAN VII compiler which have no counterparts in the P-E 3220 FORTRAN VII compiler. Second, the VAX computer provides automatic overlaying of program segments, while the P-E computer does not. Thus, VAX programs must be segmented and reprogrammed to run on Perkin-Elmer computers. Third, data files are structured differently on VAX computers from those on P-E computers, necessitating a potentially major conversion of data files. For these reasons, availability of ANSI FORTRAN VII compilers is by no means an assurance that computer programs can be readily translated from one vendor's computer to another.

2. Compatibility Among Two Computers of the Same Type

It might be thought that transfer of programs from one P-E 3200 computer to another P-E 3200 computer would be readily accomplished. However, in one test case run during the period of performance of this study, an effort was made to execute a P-E 3220 program on a P-E 3240 computer located at the Marshall Space Flight Center. The attempt failed because the P-E 3240 had a later revision of the P-E time-sharing operating system than the just installed revision of the operating system on the P-E 3220. Also, if a program is written for a large computer configuration or one with special peripheral or terminal capabilities, it may not run on a smaller or slightly different computer of the same type.

3. Compatibility with Ground Station Equipment

Compatibility with ground station equipment may be the most important constraint governing the selection of the Flight and Simulation Test Analysis System CPU. Computer programs can be converted with time and effort, computer programs can be converted from one computer to another, but interfacing ground station hardware to, and providing supporting software for, a computer for which it was not designed can be a highly formidable task.

III. CANDIDATE HARDWARE PRODUCTS

As mentioned in Section I.B., the Flight and Simulation Test Analysis System consists of three major components; a minicomputer central processing unit, a ground station with appropriate interface hardware and software, and a set of interactive terminal equipment. Additional online interfaces might be required for the Hawk radome positioner and the laser tracker, but these requirements have not yet been finalized and will not be discussed in this report.

A. Candidate Central Processing Units

Five computer product lines (discussed below) were considered for the central processing unit; the CDC Cyber 825, the SEL 32/87, the Harris 600, the P-E 3250, and the DEC VAX 11/780.

1. The Control Data Corporation 825 Computer

The CDC 825 computer is a recent addition to CDC's Cyber computer series, and is software compatible with MICOM's heavily used CDC 6600 and Cyber 176 computers. It executes instructions at a rate of about one million instructions per second (MIPS). As the user requirements survey showed, it would be quite attractive to Cyber 176 users.

The CDC 825 computer's principal liability is its high cost. A 2 MB processor costs $370,000 without peripherals, while an 8 MB processor runs $520,000. No GSA discount is available. A single 1300 MB disk drive costs $100,000 and a single 9-track, 800/1600 bpi-tape drive costs $29,000. Consequently, an 825 central processing system, including a line printer and two tape drives would cost $700,000, not including terminals or ground station equipment.

The CDC 825 computer has reluctantly been eliminated from consideration because of its high cost, and because, with its large computer architecture, it would be oversized and hard to justify for this special purpose flight data analysis application. An additional problem of serious proportions would be its incompatibility with EMR ground station equipment.

2. The Gould/Systems Engineering Laboratories 32/87 Computers

The Systems Engineering Laboratories (SEL) 32/7780 and 32/87 computers are aimed at high-speed, real-time applications. The SEL 32/87 computer is the fastest of the five computers considered for this application with a maximum computational speed of about three and one-half million instructions per second (MIPS). It is the second most expensive computer with a price tag of $280,000 for a machine with two (MB) of memory and no peripherals. The SEL 32/7780 is a dual processor computer with a computational speed of about 1.8 MIPS, and a price tag of about $235,000 with two MB of memory and no peripherals.

The SEL computers are characterized by limited software; e.g., a relatively simple operating system, and possess a maximum program address space of 131K words and a maximum data address space of 131K words. (Addresses beyond 131K words or 524K bytes are addressable through base registers.)

One advantage to using SEL computers is that similar SEL computers are located in Building 5400, and inhouse maintenance is available for these machines, as mentioned in Section II.B.5. However, this application does not require the high computational speed afforded by the SEL 32/87 and does strongly require the multitasking and interactive time sharing capabilities, large address space, and the program compatibility that is available with other computers. For these reasons, the SEL family of 32-bit minicomputers was excluded from further consideration.

3. The Harris 600 Computer

The Harris 600 computer was considered because it would be compatible with a MICOM-owned Harris 6024/6 real-time-control computer used in the Radio Frequency Systems Simulator. However, its 48-bit word size renders it incompatible with all non-Harris computers and it was excluded from further consideration.

No other minicomputer vendors such as Prime, Tandem, Hewlett-Packard or IBM were evaluated in depth for this task because of their lack of compatibility with existing Directorate equipment and because their unique attributes were not applicable to MICOM's requirements. However, Hewlett-Packard and IBM personal computers have been evaluated as interactive terminal equipment for this application.

4. Detailed Comparison of the VAX 11/780 and Perkin-Elmer Computers 3250

The two remaining contenders - the Perkin-Elmer 3250 computer and the VAX 11/780 - both deserve careful consideration and will now be compared in greater detail.

Digital Equipment Corporation is the nation's largest minicomputer manufacturer, with annual sales exceeding $3,000,000,000 per year of products ranging from single-board microprocessors to its top-of-the-line DEC System computers. DEC's inflation-corrected revenues are growing at a rate of 15% - 20% per year. The computer division of Perkin-Elmer boasts annual revenues of about $250,000,000, most of which is derived from sales of its 32 bit minicomputers. Because DEC's sales are spread out across its entire product line, while Perkin-Elmer's income is primarily derived from its 32-bit minicomputers, the disparity in 32-bit computer sales volume, and company depth between the two companies may not be as great as it seems.

Both the DEC VAX 11/780 and P-E 3250 computers are 32-bit "super-minicomputers", and both offer roughly-comparable execution speeds. Some of their salient features are outlined in Table 1 and are discussed in the ensuing pages.

a. Maximum Random Access Memory

The maximum random access memory complements for the two computers are not entirely comparable. The VAX machine automatically overlays programs and data, and automatically allocates its RAM, where RAM must be managed by the programmer on the P-E 3250. This makes it difficult to compare the VAX 8-megabyte RAM to the P-E 3250's 16-megabyte RAM.

b. Addressing

The VAX 11/780 offers the programmer virtual access memory with demand paging. This automatic overlay feature allows the programmer to write his programs as large as he wishes, up to two billion bytes in size, without having to worry about disk overlay structures and timings. However, under certain circumstances, when programs become very large, "page thrashing" can occur in which most of the computer's run time is used swapping pages between RAM and disk. This happens when, for instance, the user is randomly accessing a data array which is appreciably larger than the RAM memory which is allocated to him. The computer may be compelled to pull in a page from a disk nearly every time it accesses a number. Of course, the same problem would exist using the P-E 3250 and overlaying manually. The only difference would be that the programmer may be more aware of what is happening on a manual overlay computer than on a virtual access computer (a little like the analogy between a manual transmission and an automatic transmission).

c. Maximum Address Space Per User

The VAX computer has a 31-bit address register. This allows the user's programs and data to reach a two billion byte size (limited by disk storage capacity), even though physical memory is restricted to eight megabytes. The VAX machine automatically overlays the user's programs, so that, if the computer has two gigabytes or more of disk storage, the user can actually store and access a two gigabyte data array or program.

The P-E 3250 has a 24-bit address register, giving it an address space of 16 megabytes. This is generally adequate today but may require a fundamental redesign of the P-E computer family within the coming decade.

d. External Compatibility

As the most popular computer in its class, the DEC VAX machine which accounts for about 60 percent of all the 32-bit computer

TABLE 1
Detailed Comparison of the DEC VAX 11/780
and P-E 3250 Computers

	DEC	P-E
Maximum random access memory (RAM)	8 MB	16 MB
Addressing	Virtual	Direct
Maximum address space per user	2,000 MB	16 MB
External compatibility	1	2
Internal compatibility	3	1
Third party support (hardware and software)	1	2
User satisfaction	1	2
FORTRAN compile time	1	1
FORTRAN run time	3	4
Machine speed, Whetstones	1,200,000	1,300,000 (0 Compiler)
Guaranteed Maintenance Response Time	2 hours	24 hours
Local stockpiling of parts	2	2
Remote diagnostics	1	1
Reliability	1	2
Broad range of terminal equipment	1	4
Product stability	2	3

LEGEND: 1-Outstanding
2-Excellent
3-Good
4-Fair

installations, has a clear cut edge over the P-E 3250 computer, with about seven percent of the 32-bit market. This suggests that the majority of contractor-developed computer programs will be designed for DEC rather than P-E equipment. (For what one case is worth, converting the TRW Pershing II FORTRAN program from the VAX machine to the P-E 3250 is turning out to be difficult.)

e. Internal Compatibility

The Directorate already owns a Perkin-Elmer 3220 computer and a Perkin-Elmer 8/32 computer and there is much to be said for buying another computer which is compatible with them. FORTRAN programs may have to be recompiled going from the P-E 8/32 to the P-E 3250, and sometimes, from the P-E 3220 to the P-E 3250. However, with eight MB of RAM on the P-E 3250 and one MB of RAM on the P-E 3220 and the P-E 8/32, it may not always be feasible to convert programs from the P-E 3250 to the other two computers. Data disk packs from one machine should be usable on another, although different levels of the operating system might sometimes interfere with this.

With respect to VAX compatibility, the U.S. Army Missile Laboratory owns six VAX 11/780 computers. Thus, computational backup would also be available if a VAX computer were selected. Conversion of FORTRAN programs between the VAX machines and Perkin-Elmer computers would, at the very least, require recompilation. Also, data disks would have to be reformatted.

All these computers have 67 megabyte disk drives and nine-track tape drives. The VAX machines and one of the Perkin-Elmer computers also have 256 megabyte removable pack disk drives.

f. Third-Party Support (Hardware and Software)

Because of DEC's 60-65 percent dominance of the 32-bit computer market, a "bandwagon" effect has developed with respect to software and third party vendor supplied hardware. A lot of software and accessories are available for VAX computers that are not available for other brands.

g. User Satisfaction

Table 2 summarizes the results of a user satisfaction survey conducted by Datapro among users of the P-E 3220 and the DEC VAX 11/780. The P-E 3220 users consisted of a public utility, a bank systems supplier, and three development systems houses. One user had six computers, one had five, one had three, and the other two had one each. Languages in use consisted of FORTRAN, BASIC, COBOL, PL1 and RPG II.

TABLE 2
User Satisfaction Survey

	P-E Models	DEC VAX Models
Ease of Operation	2.63	3.70
Reliability of Mainframe	3.29	3.65
Reliability of Peripherals	2.67	3.15
Maintenance Service:		
Responsiveness	2.67	3.09
Effectiveness	2.50	3.04

NOTE: System Ratings 4.0 - 1.0

h. FORTRAN Compile Times and Run Times

Perkin-Elmer supplies three FORTRAN compliers with its 32-bit computers. These are a development (D) compiler, an optimizing (O) compiler, and a global super-optimizing (Z) compiler. The development compiler runs reasonably fast, but generates inefficient code (which, reputedly runs at one-third to one-half the speed of optimized code). The optimizing compiler, generates efficient code but compiles at one-third to one-half the speed of the D compiler (too slow to be of much use to MICOM). The Z compiler produces globally optimized code but literally compiles all night to compile a large program. Experience within the Directorate shows that, on the Directorate's existing Perkin-Elmer computers, the compiling speed for the O compiler is already too slow to be useful, so that virtually all work is done with the D compiler.

Digital Equipment supplies one universal FORTRAN compiler which compiles faster than the Perkin-Elmer D compiler and generates code that is well-optimized.

As a result, in comparing these two computers, one must recognize that FORTRAN programs may run considerably faster on the VAX 11/780 than they do on the P-E 3250 even though the two computers have comparable machine language execution speeds.

i. Machine Speed, Whetstones

This test, written in FORTRAN, runs the computer through a mix of operations that represent the computational mix in the "average" FORTRAN program. Presumably, Perkin-Elmer used its O compiler for this operation.

j. Guaranteed Maintenance Response Time

If awarded a maintenance contract, DEC will guarantee placing a repairman on site within two hours after receiving a call for service.

If awarded a maintenance contract, P-E will guarantee that a repairman will telephone within four hours after receiving a call for service. There is no guarantee about when the repairman will arrive (he might be out-of-town) but a reasonable worst case expectation would be on-site arrival within twenty-four hours of receiving a call.

k. Local Stockpiling of Parts

Both companies maintain large local parts inventories. DEC claims a $6,000,000 parts inventory, including replacements for any DEC computer board in the Huntsville area. P-E claims a similar board replacement capability in its parts depot.

l. Remote Diagnostics

Both companies rely heavily on computerized diagnostic programs accessed over long-distance telephone lines. The VAX computer has a built-in microprocessor to allow it to conduct the remote diagnostic program when the main computer is down.

m. Reliability

Based on user reports, the VAX 11/780 computer probably has a slight edge in reliability over the P-E 3250. However, both computers have a reputation for high reliability when they are maintained by the vendor.

n. Range of Available Terminal Equipment

Perkin-Elmer provides only two types of terminals: a $700 alphanumeric terminal CRT and a $1500 alphanumeric CRT terminal. Experience reports from within the Directorate indicate that the $700 terminals have performed here in a less than satisfactory manner.

Digital Equipment markets a broad line of terminal equipment. Among its key products are the VT-100 Alphanumeric Terminal, the VT-125 Graphics Terminal, the 325/350 Personal Computer, and the LA-100 DEC Writer. DEC provides support software for these terminals.

o. Product Stability

DEC offers a stable slow-turnover product line. The VAX 11/780 computer was introduced in 1977 and is expected to remain a current product for at least the next year. After that, replacement parts will be available from DEC for at least ten years. P-E has had a higher rate of turnover. The Perkin-Elmer 3240 was introduced in 1979 and became obsolete in 1981. However, Perkin-Elmer has just introduced the P-E 3250 so that its product life should be several years. Perkin-Elmer also guarantees replacement parts for a ten-year period.

B. Candidate Ground Station Equipment

Three ground station products were considered for the ground station portion of the Flight and Simulation Test Analysis System. They were a Government-owned Hewlett-Packard (HP) 5451C Fourier Analyzer, the EMR EXPRT ground station, and the EMR 700 series of ground station components.

1. The Hewlett-Packard (HP) 5451C Fourier Analyzer

Since it is already Government-owned, the HP 5451C Fourier Analyzer would be the least expensive of the ground station equipment surveyed. However, it is heavily used and its availability for the Flight and Simulation Test Analysis System might prove to be a problem. Also, it is limited to four simultaneous data input channels, with a digital to analog conversion rate per channel of 25,000 samples per second. It is not equipped to support the subcommutated data frames which are present on Pershing II flight test tapes. For these reasons, the HP 5451C has been ruled out for this application.

2. The EMR EXPRT Data Reduction System

The EMR EXPRT System offers a conveniently packaged ground station with a rather low level of data reduction capability (comparable to the HP 5451C). Its principal advantage resides in the fact that it contains its own LSI-11 microcomputer with some resident data reduction software. This would permit it to be attached to any computer through a high speed serial port. Unfortunately, its data reduction capabilities are considered to be inadequate for this application and it must, therefore, be eliminated from consideration.

3. The EMR 700 Data Reduction Components

The most expensive and the most capable ground station equipment considered for this application is available only with parallel interfaces to DEC computers. Also, the vendor's extensive TELEVENT software support package is written in assembly language for DEC computers. If it is necessary to interface this equipment to another computer, then the most satisfactory approach might be to buy a small DEC computer to support the ground station equipment and then to interface the DEC computer to the other computer. However, this would be expensive and cumbersome. The ground station requirement for DEC compatibility appears to be a strong driver in the selection of a host computer.

C. Candidate Terminal Equipment

1. Video Display Terminals

a. Video Display Technologies

There are basically three types of video display technologies available today; the Tektronix direct view storage display, the vector-drawing graphical display, and the raster or video (TV type) graphical display.

(1) The Direct View Storage Display

The direct view storage display is manufactured only by Tektronix and affords the highest resolution and greatest information display of any graphics display on the market. The storage display tube uses a proprietary bistable phosphor coating that has the property of glowing brighter than the surrounding phosphor once it has been "triggered" by a high intensity electron beam. This property eliminates the need for computer memory to continually refresh the image on the screen. The prices of these displays have not dropped since they were first introduced in 1968, while raster graphics prices have declined precipitously and are continuing to do so. Other limitations of these storage displays reside in their inability to selectively erase portions of the screen and in the low brightness of the display. There is no substitute for them where very high quality graphics is required, but they have become relatively high priced.

(2) Vector Graphical Displays

Vector graphical displays can typically display up to several hundred vectors on a screen by refreshing the image 30 to 60 times a second. They are relatively expensive because of their requirement for very rapid deflection cathode ray tube circuitry and for high speed digital to analog converters. They are also quite restricted in the amount of information that they can display on a screen before flicker sets in. Vector graphical displays have nearly disappeared because of their inherently high cost and limited information display capabilities.

(3) Raster Graphical (Television-Type) Displays

Raster graphical displays use the familiar cathode ray tube approach of modulating a horizontally swept electron beam to paint complex material upon a phosphor coated screen. The images presented on the screen can be as complex as a television picture. The computer refresh memory required by this approach was prohibitively expensive until a few years ago, but rapidly declining RAM prices are permitting lower and lower cost raster graphical displays.

All three of the above display technologies will support at least three- or four-color displays, but only the raster graphical units allow a broad range of colors and hues. Raster graphics are clearly the wave of the present and the future, and will now be discussed at some length. Some features which need to be considered in selecting video display computer terminals are cited below.

b. Factors to Consider in Selecting Raster Graphical Displays

(1) Flicker

High quality video display terminals are refreshed 40 to 60 times a second in a repeat field mode to avoid flicker. The repeat field mode is one mark of a high quality video display. Lower-quality display terminals sometimes use the interlace mode employed in conventional television sets, wherein alternate lines of the display are refreshed 24 times a second. While this is suitable for television reception, it becomes annoying and conducive to eyestrain when displaying text and graphical material in an office setting. One flicker remedy for monochromatic interlaced displays lies in the use of a long persistance phosphor, although this causes after-image effects.

(2) Jitter

Some low cost terminals have unstable circuitry which allows images to jitter slightly, causing potential eyestrain.

(3) Horizontal Resolution

How sharp the edges of a vertical line will appear depends upon the bandwidth of the horizontal amplifiers in the video monitor. For example, the IBM personal computer display affords very sharp, well-defined lines in both the horizontal and vertical directions. Low cost personal computers often use television sets or low quality video monitors and yield fuzzy images.

High quality monochromatic video monitors are available for $200 to $300 while high quality color monitors cost $800 to $1500.

(4) Electro-Optical Distortions

Low cost video monitors and television sets have curved screens and electro-optical distortions that cause pin cushion distortion near the edge of the screen. These effects can be annoying when displaying charts and plotted curves.

(5) Raster Effects

One effect of a discrete set of raster scan lines is that on some video displays, vertical lines take the form of a series of dots. This is the case on the Hewlett-Packard and Apple graphics displays. On others, such as the IBM personal computer and the DEC Video Terminal (VT) 100 Series of terminals, the vertical lines are solid, and solid areas can be filled in.

Another unavoidable raster graphics effect is the staircase effect. On Tektronix storage terminals and on vector graphics displays, smooth diagonal lines may be drawn. However, the discrete nature of raster scan lines insures that diagonal lines will exhibit a staircase effect that is particularly noticeable when the lines are nearly horizontal. The greater the number of raster lines, the less this effect will be. Thus, for raster graphics displays, a large number of raster scan lines is desirable.

Software compatibility among terminals is an important consideration. Otherwise, a user would be able to run his graphics computer programs only through terminals which are compatible with his program.

c. Descriptions of Specific Video Display Terminals

(1) Alphanumeric Terminals

Alphanumeric terminals are available in "dumb" or "smart" form and typically cost $600 to $1500. "Smart" terminals have local page storage and editing features that can help reduce the input/output burden on the central computer. Some good quality alphanumeric display terminals are made by DEC, Televideo, Hewlett-Packard and Tektronix.

(2) Graphical Display Terminals

(a) Digital Equipment Corporation (DEC) Video Terminal (VT) 100 Terminals

In addition to the criteria specified above, graphical terminals are specified by their dot resolution. Among the recommended graphical terminals are the DEC VT 100 terminal family with Retro-Graphics or Selenar graphical display boards at a minimum cost of about $2300. These terminals can provide graphical dot resolution of 200 by 640 pixels in a repeat-field mode or 400 by 640 pixels in an interlaced mode with a long persistance tube.

(b) The Hewlett-Packard 2623 Terminal

Another attractive graphics display terminal is the Hewlett-Packard 2623 display, costing about $2900 after GSA discount, and providing about 380 by 512 pixel dot resolution.

(c) The Tektronix 4025 Raster Graphical Terminal

A third low cost graphics display is the Tektronix 4025 raster graphics terminal, costing about $5000 after GSA discount, and providing 480 by 640 pixel dot resolution.

(d) The Tektronix 4006-1 Storage Display Terminal

A fourth low cost graphical display terminal is the Tektronix 4006-1 storage display terminal costing $3060 after GSA discount, and providing 780 by 1024 pixel resolution. One disadvantage to this terminal lies in its requirement for a $3900 Tektronix photocopier in order to obtain hard copy at the terminal. All of the above displays are compatible with the Tektronix plotting software packages.

(3) Color Graphical Displays

A number of color graphical display terminals may be recommended.

(a) The Tektronix 4113 Color Terminal

The Tektronix 4113 color terminal costs $15,000 and up, and provides 480 by 640 pixel resolution. It has many features such as rubber banding of images and local image rotation and manipulation which may or may not be needed for this application.

(b) The Tektronix 4027 Color Terminal

The Tektronix 4027 color graphics terminal costs $8500 and up, and provides 480 by 640 pixel resolution.

(c) The Itoh Plug-Compatible 4027-Equivalent Terminal

Itoh Corporation is expected to announce a $3,000 plug-compatible copy of the Tektronix 4027 color graphics terminal by December, 1982. This terminal is inexpensive enough that it might be used at individual desks. Itoh has a satisfactory reputation as an equipment vendor, although purchase of this equipment might run counter to the Federal "Buy American" policy.

2. Plotters

Two price level plotters were examined for this application.

a. The Tektronix 4662 Plotter

The Tektronix 4662 eight-pen color plotter is software compatible with the Tektronix 4027 and 4113 color graphics terminals. It is relatively expensive, costing about $4600, and is probably best suited for shared use at a central site.

b. The Houston Instruments Hiplot Plotter

The Houston Instruments Hiplot Plotter is a single-pen plotter, suitable for remote terminals which costs about $1,000 and is manufactured by the Houston Instrument Division of Bausch and Lomb. This company also sells a two-pen plotter for about $1,400 which is also marketed by Hewlett-Packard for their HP 86 personal computer. Both of these plotters can generate colored plots by making multiple passes with different colored pens.

3. Terminal Printers

a. Dot Matrix Printers

Present day dot matrix printers use very closely-spaced styli to generate printer quality letters at high speeds (100 to 240 characters per second), or typewriter quality letters at low speeds (30 characters per second), or graphical plots on either chemically treated or untreated paper. They are available with either friction or pin feed platens with varying platen widths.

(1) The Epson MX-100 Printer

A de facto standard low cost terminal printer is the Epson MX-100 series, which IBM and Hewlett-Packard are using for their personal computers. It costs between $600 and $800, depending upon options and uses specially treated paper.

(2) The LA-100 Digital Equipment Corporation DECwriter

The DEC LA-100 DECwriter is a higher priced, heavier duty matrix printer which costs about $2100 after GSA discount and uses untreated paper.

b. Daisy Wheel Printers

Daisy wheel printers use Selectric-like interchangeable print wheels to print on untreated paper at rates ranging from 12 to 55 characters per second. They are used in word processing applications to print typewriter quality output.

(1) Low Cost, Light Duty Printers

Royal Typewriter Corporation has recently advertised a 12-character per second daisy wheel printer selling for $900. Anderson-Jacobsen has also announced a low cost daisy wheel printer.

(2) Heavy Duty Printers

Higher priced heavier duty daisy wheel printers selling for $2300 to $2700 are available from Diablo, Qume, and Nippon Electric Company.

c. Color Printers

Several types of color printers are available.

(1) Ribbon Printers

The least expensive type is the dot matrix printer, using four different colored ribbons and multiple passes. The drawback to this type of printer is cross-contamination of colors, since ink from one ribbon is deposited on other ribbons during successive passes. Ribbons must be replaced often and the styli must be cleaned frequently. The lowest priced multi-ribbon printer is the recently announced Idiom Prism printer retailing for $2100.

(2) Ink Jet Printers

The next level of capability and cost is represented by the ink jet printers. These use electrostatic force to control the flow of electrically charged ink droplets from three primary color ink sources.

Tektronix Corporation has recently announced an ink-jet printer that sells for about $12,000. Another low cost ink-jet printer is manufactured by Intelligent Systems Corporation of Norcross, Georgia, selling for about $5500.

The highest level of capability and cost is exemplified in a laser based color printer marketed by Xerox Corporation and selling for about $20,000.

4. Personal Computers/Terminals

Competition among personal computer vendors has caused personal computer prices to rival those of simple terminals. The use of personal computers as terminals offers important advantages over basic terminals. A major advantage lies in the ability to transfer source program and data files from the central computer to the personal computers, where they may be edited and listed without continually interrupting the central computer. Data entry and formatting of graphical and text output can also be carried out offline. Another advantage lies in the ability to run small programs offline when the central computer is unavailable. Their major disadvantage lies in their lack of a suitable terminal emulation package.

a. Low-Cost Personal Computers/Terminals

Low cost (less than $1000) personal computers have some significant disadvantages. First, their graphics capabilities are marginal, with a maximum resolution of 200 vertical by 320 horizontal pixels. Second, their alphanumeric displays are limited to 40 characters per line by 25 lines. However, printed circuit cards are available to convert them to 80 characters per line by 25 lines. Third, lower case characters are generally unavailable (although available from independent vendors). Fourth, although these devices can drive color displays, suitable quality color monitors are very expensive, ranging from $800 to $1500. Therefore, the low cost advantage of these units is lost when they are used as color graphical terminals.

A few of these low cost personal computer and their characteristics are listed below. Total prices include $250 for a high quality monochromatic video monitor and $100 for a printed circuit card to provide upper and lower case characters and 80 characters per line.

- Texas Instruments 99/4A
  Base Price: $200
  Graphics: 192 x 256 pixels, 16 colors
  Alphanumerics: 16 lines x 32 characters per line
  RAM: 16K bytes
  Total Price: $700

- Commodore 64
  Base Price: $480
  Graphics: 200 x 320 pixels, 16 colors
  Alphanumerics: 25 lines x 40 characters per line
  RAM: 64K bytes
  Total Price: $730

- Radio Shack Color Computer
  Base Price $300
  Graphics: 192 x 256 pixels, 1 color
  Alphanumerics: 16 lines x 32 characters per line
  RAM: 16K bytes
  Total Price: $700

Other low cost personal computers such as the Commodore VIC-20 and the Atari 400 were considered for this application but were rejected as clearly inadequate. Only the Commodore 64 is considered to be a competitive candidate for this application and then only if a computer card can be found that provides upper and lower case text with 80 characters per line.

b. Professional Quality Personal Computers/Terminals

Hewlett-Packard, IBM and DEC offer professional quality personal computers which could make satisfactory graphics display terminals. The Apple II and Apple III computers were also investigated for this application but were rejected on the basis of low graphics resolution. Among them, only the IBM Personal Computer can support other terminals in a time sharing mode and then only one or two terminals in a marginally satisfactory way.

A principal limitation upon using these personal computers as terminals is that, although they are designed to be used as alphanumeric terminals, they are not designed to function as graphics terminals. In practice, this means that graphical plots have to be transferred from the host computer to the personal computer in the form of data files, which the personal computer then displays upon command. Some additional data characterizing these personal computers are listed below.

o The Hewlett-Packard 86 Personal Computer

GSA Price: Approximately $2,000
Graphics Resolution: 380 x 512 pixels, monochromatic only
RAM: 64 kilobytes
Programming Languages: BASIC
Minifloppy Disk: $650 extra
Printer: $800 extra
Microprocessor: 8-bit (slow running)
Comments: Although not so advertised, the HP-86 should be hardware compatible with the Tektronix plotting software. Raster scan lines are visible on the HP-86, so that vertical lines appear to be rows of dots. Otherwise, its graphical display capabilities are excellent.

o The IBM Personal Computer

List Price: $2300
Graphics Resolution: 200 x 640 pixels
RAM: 64 kilobytes
Programming Languages: BASIC, FORTRAN, COBOL
Minifloppy Disk: $650 extra
Printer: $750 extra
Microprocessor: 16-bit 8088
Comments: The graphical display is excellent on the IBM Personal Computer. Both vertical and horizontal lines are continuous and sharp-edged, and solid areas of illumination can be filled in. However, some manipulation of the TEKplot output files would be required to render them compatible with the IBM 200 x 640 pixel display format.

o The DEC 325 Professional Computer

GSA Price: $3300
Graphics Resolution: 240 x 960 pixels
RAM: 256 kilobytes (standard)
Programming Languages: BASIC, FORTRAN VII, PASCAL, etc.
Minifloppy Disk: Two (standard)
Printer: $2100
Microcompressor: LSI 11/23+
Comments: This personal computer is attractive because of its compatibility with VAX software, and because of the great range of software available for the DEC PDP 11 computer family. Tektronix plot files would have to be preprocessed (dividing vertical scale values by 3) to run them on this display. The graphical display quality of this device has not been evaluated because of its unavailability.

o The DEC VT103

GSA Price: Approximately $3600
Graphics Resolution: 200 x 640 pixels; 400 x 640 pixels in interlace mode
RAM: 64 kilobytes
Programming Languages: BASIC, FORTRAN VII, PASCAL, etc.
Minifloppy Disk: $850
Printer: $2100
Microprocessor: LSI 11/2, LSI 11/23
Comments: The graphical display quality has not been evaluated because of unavailability of the display. This terminal is designed to be compatible with Tektronix software.

D. Centralized Versus Distributed Processing

A sizable fraction of an interactive computer's capacity is dissipated in responding to users' editing and output formatting interruptions. Three approaches which are commonly used to relieve the central processor of this busy work and also, to provide backup in case the main frame is unavailable are a front-end processor, or the use of distributed minicomputer modes, or the use of personal computers.

1. Front-End Processor

The front end processor concept uses a cheaper, software compatible edition of the main computer to interface with the telephone lines and remote terminals. Files are transferred en bloc from the main computer's disk to the auxiliary computer's disk with a minimum of overhead and are later returned to the main computer's disk when modifications are complete. If a VAX 11/780 computer is used as the main processor, a VAX 11/730 computer is recommended as the compatible front end processor at an extra cost of $30K to $50K, depending upon options.

2. Distributed Processing through Nodal Minicomputers

This approach uses one or more minicomputers located remotely from the central processor and tied to the central processor by coaxial cables. Each minicomputer supports four to eight local time sharing terminals for data and program entry, editing, output formatting, and uses files transferred at high speed (one megabyte per second) between the central processor and the local network computer. A candidate computer for this purpose would be the DEC Micro-11, with a 10-megabyte disk and a $10,000 price tag. (No more than two high speed one-megabyte per second links can be attached to a UNIBUS. Thus, this approach would probably entail some additional expenses.)

3. The Use of Personal Computers

The advantages and limitations of this approach have been discussed in Section III.C.4. It is probably a less advantageous and cost effective way to reduce the input/output burden on the central computer than the use of a front-end processor or nodal minicomputers, for this reason: When a central computer can block-transfer programs or data to a peripheral device at RAM speeds through a direct memory access channel, the central computer is only interrupted long enough to set up the transfer. Thereafter, while the transfer is taking place, the computer can resume its other activities. However, when data is transferred at a lower rate, the computer becomes tied up for a number of machine execution cycles for each character of information. Both the front-end processor and the nodal minicomputer could transfer information to and from the central computer at these block transfer rates, while the personal computers could not. This means that, although the personal computers would interfere less with the central computer's "number crunching" activities than would simple terminals, they would be more disruptive of the central computer's workload than would either the front-end processor or the nodal minicomputers.

IV. RECOMMENDATIONS AND CONCLUSIONS

A. Recommended Computer System

After evaluation of the requirements and the available resources, it is recommended that a DEC VAX 11/780 32-bit minicomputer be purchased as the host computer for the Flight and Simulation Test Analysis System as discussed below.

1. Justification

a. Ground Station Compatibility

Hardware and software compatibility with the EMR ground station is a requirement for the computer system which is to be selected for this application. The cost of developing interface hardware and/or software for other computers with which the EMR equipment is not designed to operate would presumably be quite high, on the order of hundreds of thousands of dollars. Equally important would be the problem of maintaining special interface hardware and software over the next decade. For this reason, the DEC VAX computer appears to be the best available choice.

b. Virtual Access Addressing

The availability of virtual access addressing on the DEC VAX computer is also held to be an important requirement in the programming environment in which the Flight and Simulation Test Analysis System operates. There will be a number of inexperienced programmers using the machine. For them, the ability of the VAX computer to run large imported programs without having to restructure the programs into different disk overlays may spell the difference between success and failure. Also, virtual addressing would permit programs on large VAX computers to be run on smaller VAX computers without reprogramming. This means that smaller MICOM VAX computers could provide immediate backup to the Flight and Simulation Test Analysis System's large VAX computer.

c. General User Satisfaction

Both discussions with other VAX users and a Datapro survey of minicomputer users indicated that the DEC VAX computers were favored over the P-E 3200's for computer use which was aimed primarily at program development (Reference 1). The Datapro survey showed that 92.59 percent of the VAX computer owners would recommend to the purchase of a VAX computer to other users, compared to 70.83 percent of the P-E computer owners.

2. Recommended Computer Configuration

It is recommended that the VAX computer be purchased with eight megabytes of random access memory, 1000 megabytes of systems disk storage, and two, 1600/6250 bits per inch, 125 inch per second, 9-track tape drives. Also recommended for purchase are input/output equipment consisting of one 600 to 1000 lines per minute line printer; one 600 to 1000 card per minute card reader; and one Versatec printer/plotter.

a. Random Access Memory

A full eight MB of RAM is recommended for this computer because eight to ten large programs are expected to run simultaneously in it. Furthermore, over the next decade, computer RAM memory capacities are expected to increase by one to two orders of magnitude, and program sizes are expected to keep pace with these computer capacities. This will lead to ever increasing demands for RAM as larger and larger data analysis and simulation programs are developed and run on the Flight and Simulation Test Analysis System during the coming years.

b. Disk Drives

Extensive disk memory is required because large quantities of raw data must be stored on-line for this data analysis application. Economies of scale favor the use of large capacity disk drives since a 512-megabyte RK07 disk drive costs only a little more than a 256-megabyte disk drive. A 256-megabyte RP05 removable pack disk drive is required to be compatible with the other VAX computers in Building 5400. A second 256-megabyte removable pack disk drive is desirable to provide disk to disk copy capability and to furnish back up in case one disk drive is unavailable. A 512-megabyte disk drive is quite advantageous because it possesses nearly twice the data transfer rate and lower rotational latencies than the 256-megabyte disk and it permits the computer to run faster than is possible with smaller disk drives.

The purchase of four to eight 67-megabyte disk drives is recommended. These are user disk drives on which each active user will mount his own personal disk pack. At least one of these disk drives is mandatory. It is desirable to have enough of these to accommodate all the simultaneously active users. Otherwise, each active user must transfer his relevant files to the system disk at the beginning of his run. Then he must remove his disk pack, and come back later remounting his disk pack to pick up his results. If the computer calls for other unanticipated files during the run, his disk pack will not be there to supply them.

c. Tape Drives

At least one of these high capacity tape drives is required to back up the systems disk. Lower density tapes do not have the data transfer speed or storage capacity to back up such a large disk in a practical manner. Two such tape drives are recommended to allow tape to tape copy capability, since this may not be available anywhere else at MICOM.

d. Other Input/Output Equipment

One heavy duty high speed line printer is considered essential for the production output of data. A second printer such as a matrix printer/plotter is also recommended for backup and for complementary capability. Card input equipment is still heavily used within the Branch. A 600 to 1000 card per minute card reader would be inexpensive and well worth having. A Versatec printer/plotter is recommended for high speed production printing and plotting of data output, since large volumes of output plots are frequently generated by Branch personnel.

B. Recommended Ground Station Equipment

It is recommended that EMR 700-series equipment be selected for the ground station portion of the Flight and Simulation Test Analysis System.

1. Justification

The Hewlett-Packard 5451C Fourier Analyzer is inadequate for the task at hand and is also all but unavailable for this purpose. Similarly, the EMR EXPRT system is too limited in capability to support this application. Consequently, the EMR 700 equipment becomes a clear and necessary choice for this application.

2. Recommended Ground Station Configuration

The following list of ground station equipment is recommended.

- Sabre 80 14-channel analog tape drive
- EMR 429 programmable multiplexer with 2x4, 10-bit sample and hold
- EMR 575 pulse amplitude modulated decoder
- EMR 710 pulse code modulated decommutator with simulator and subframe synchronizer
- EMR 720 pulse code modulated bit synchronizer

- o EMR 742 time code translator with slow code
- o EMR 760 buffered data channel with wired base plate
- o EMR 760 buffered data channel
- o EMR 4150 filter with seven-pole filters
- o Televent software for the DEC VAX computer

C. Recommended Terminal Equipment

1. List of Recommended Terminal Equipment

The following is a list of recommended terminal equipment.

Number	Company	Model	Terminal	Operational Mode
2	Tektronix	4116	19" Storage Display	Shared
2	Tektronix	4027	Color Graphics	Shared
1	Tektronix	4691	Ink-Jet Printer/Plotter	Shared
2	Tektronix	4662	8-Pen Color Plotter	Shared
2	Tektronix	4006-1	9" Storage Terminal	Assigned
4	Tektronix	4612	Hard Copiers	Assigned
10	DEC	VT103	Alphanumeric Terminal	Assigned
6	DEC	VT103	Graphics Terminal	Assigned
1	DEC	LA-100	DECwriter Matrix Printer	Shared
4	Epson	MX-100	Low Cost Printer/Plotter	Assigned
6	Houston Instr.	Hiplot	Low Cost Plotter	Shared
1	Qume		Daisy Wheel Printer	Shared
2	Houston Instr.	Hipad	Graphic Input Tablets	Shared

2. Discussion of Recommended Terminal Equipment

a. Tektronix 4116 19-Inch Storage Display Terminal

The user survey (Section II.A.) showed that the Tektronix 4116 19-inch storage display terminals are desired above all other graphics output displays. The recommendation has been limited to two of these terminals because of their high ($16,000) base price.

b. Tektronix 4027 or 4113 Color Graphical Displays

Two of these medium cost ($10,000) high quality, commonly shared, color graphics terminals are recommended. The rapidly declining cost of color graphics, and its rapidly growing prevalence in personal computers insures that color graphics output will become a common feature in computer programming over the next decade. Color graphical capability is regarded as a "play toy" frill today because users are unfamiliar with its advantages and because color-based software, printers, and

copiers have been too expensive to be available to most users. This picture is now changing rapidly as under $200 color based home computer prices and $200 home computer color printers expand the color graphics market and stimulate lower cost color technology. Purchasing two of these color graphics terminals will permit the evaluation of color graphics and will support contractor developed programs that are designed for color graphics output as these appear over the next few years.

c. Tektronix 4691 Ink Jet Printer/Plotter

This color printer/plotter will permit the production of low cost color hard copy. Color hard copy is essential if color graphics are to be used to good advantage.

d. Tektronix 4662 Eight-Pen Plotters

Two of these flat bed plotters are recommended to support the Tektronix 4027 or 4113 color graphics terminals. These flat bed plotters can provide color viewgraphs and can ink in solid areas. They can also be run in black and white and color production modes when a large number of plots is required.

e. Tektronix 4006-1 Nine-Inch Storage Display Terminals

Two of these low cost ($3,000) Tektronix terminals are recommended because of the popularity of storage graphics displays. Unfortunately, these terminals require expensive hard copy units. Up to four terminals can share one photocopier provided they are located in the same room.

f. Tektronix 4612 Hard Copiers

Two of these $4,000 hard copy units have been recommended to allow the two 4006-1 storage terminals to be used at separate locations. However, one photocopier could be shared by the two terminals if they are located near each other. Two other 4612 hard copiers are required to provide hard copy for the two 4116 storage display terminals.

g. DEC VT 103 Alphanumeric Terminals

The DEC VT 103 alphanumeric terminals have been recommended as a standard desk top terminal because they are upgradable to graphics display terminals and to stand-alone computers with plug-in cards. Also, they are DEC compatible, which would simplify maintenance.

Finally, $800 Epson MX-100 printers may be used with them to provide low cost hard copy at each terminal. Sixteen VT 103's are recommended for individual or office use at a price of about $1,300 each, plus $800 for Epson printers where these are needed. Of these, six would be located in contractor offices. An alternative approach would entail the use of Tektronix 4025 black and white graphics terminals at a cost of about $5,000 after GSA discount. These provide higher resolution (480 by 640 pixel) resolution at a higher cost. They are not upgradable to personal computers.

h. DEC VT 103 Graphics Display Terminals

DEC does not provide a plug-in graphics board for the VT 103 but does provide maintenance for a $1,000 to $1,200 graphics board manufactured by Retro-Graphics and sold in Huntville by Highsmith and Company. Four to six of these graphics boards are recommended for the VT 103 terminals. It is also recommended that one or two of the terminals be equipped with LSI 11/2 or LSI 11/23 boards to convert them into smart terminals with limited standalone capabilities.

i. DEC LA-100 DECwriter

One LA-100 DECwriter is recommended to provide letter quality output for word processing applications or high speed output for data processing applications.

j. Epson MX-100 Low Cost Printer/Plotters

Twelve to sixteen $800 Epson MX-100 printers/plotters are recommended t provide hard copy from the VT 103 terminals if the Epson printer can be attached to the VT 103. Hard copy is an important requirement at a terminal.

k. Houston Hiplot Low Cost Plotters

Four to six low cost ($1,000) Hiplot plotters are recommended for individual office use to provid light duty high quality plotting capability at remote sites.

l. Qume Daisy Wheel Printer

One Qume daisy wheel printer is recommended to support word processing output from the system. The Qume printer is recommended because it is compatible with the CPT printers in use at MICOM and because it is a rugged, heavy duty printer.

m. Houston Hipad Graphic Input Tablets

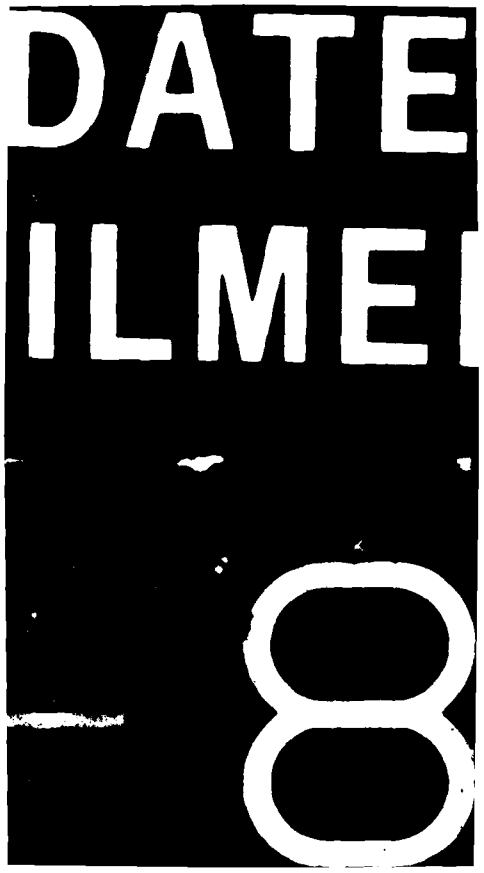
It is recommended that at least two, low cost, ($1,000) graphic input tablets be purchased for the system. Some digitizing of data is presently required within the Branch. It may also be desirable to buy one high quality Tektronix graphics input tablet to be used in conjunction with one of the Tektronix terminals.

REFERENCES

1. A Datapro Feature Report: User Ratings of Computer Systems, Datapro Research Corporation, Delran, NJ, 1982.

DISTRIBUTION

	No. of Copies
Georgia Institute of Technology Engineering Experiment Station Atlanta, GA 30332	5
DRSMI-LP	1
-RDF	5
-RPR	15
-RPT	1


DATE
ILME
8